MS 3501-R

Trading apples for oranges?
Results of an experiment on the effects of heroin and cocaine price changes on addicts' polydrug use

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ABSTRACT:

This paper studies polydrug use patterns in heroin and cocaine addicts. We use data on two experiments to measure the elasticity of several addictive drugs with respect to heroin and cocaine prices. Own and cross price elasticities are estimated while controlling for non-price related sources of variance. The results indicate that heroin addicts have an inelastic demand for heroin, complement heroin consumption with cocaine, marijuana, and alcohol and substitute Valium and cigarettes. Additionally, heroin addicts' cocaine consumption is inelastic, and they substitute cocaine with marijuana and Valium, and complement it with alcohol. Cocaine addicts have an elastic demand for cocaine; they complement cocaine with heroin and alcohol and substitute it with marijuana and Valium. Cocaine addicts' demand for heroin is inelastic; and, for this group, alcohol is a complement to heroin while cocaine, marijuana and Valium are substitutes to heroin.

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1. Introduction

Illicit drug users consume a variety of drugs, with estimates indicating that 50% of heroin addicts use alcohol, 33% benzodiazepines, 47% cocaine, and 69% marijuana (Ball and Ross, 1991). Prevalence of marijuana and alcohol abuse in cocaine addicts ranges from 25 to 70% (Higgins et al., 1991; Schmitz et al., 1991), and between 60 and 90% of substance abusers smoke (Budney et al., 1993; Stark and Campbell, 1993). Polydrug abuse presents problems for treatment and public health initiatives. Most drug-related emergency room visits involve combinations of alcohol and multiple illicit drugs (NIDA, 1991). Polydrug abuse increases the likelihood of overdose (Risser and Schneider, 1994), participation in HIV risk behavior (Petry, 1999), and poor compliance with treatment (Ball and Ross, 1991). Thus, the question of how drug users complement and substitute their main addictions as prices change is important and relevant for policy design.

Despite the prevalence and problems of polydrug use, relatively little economic literature has focused on how prices influence polydrug use patterns specifically in addicted populations. We use Deaton and Muellbauer's (1980a) Almost Ideal Demand System to examine substitution patterns. Given a budget and a set of street prices, substance abusers change drug purchases as heroin and cocaine prices vary. Implicitly, we assume that preferences are separable for addictive and all other goods.[1] We estimate two specifications. First, we impose the *no-free lunch* condition that ensures individuals cannot spend more than they have. Second, we impose two micro-economic consumer theory constraints on the coefficients known as *homogeneity* (a proportionate change in income and prices will leave consumption of any one good unchanged) and *symmetry* (cross-price responses of any pair of goods are equal when price changes are compensated by equivalent income changes such that real income and utility remains intact).

[1] This assumption has been used extensively in demand estimation in other fields. And, although for simplicity we interpret the budgeting procedure as a two-stage procedure, the functional demand form we use (Almost Ideal Demand System) ensures the satisfaction of the necessary and sufficient conditions for the budgeting procedure to be consistent with a one-stage procedure. I.e., the group indirect utility functions have a generalized Gorman polar form and the overall utility function is additive, see Deaton and Muellbauer (1980b).

We compare our experimental results to those obtained from real world situations. Because our estimates lie comfortably within the ranges of previously estimated elasticities, we argue that our methodology may be a valid mechanism to elicit preferences from special populations. Moreover, characteristics of our sample are similar to characteristics of general addict populations.

We find that heroin addicts have an inelastic demand for heroin. Heroin addicts also complement heroin consumption with cocaine, marijuana, and alcohol, but they substitute it with Valium and cigarettes. Heroin addicts' cocaine consumption is also inelastic; they substitute cocaine with marijuana and Valium, and they complement it with alcohol. In contrast, cocaine addicts have an elastic demand for cocaine; they complement cocaine with heroin and alcohol and substitute it with marijuana and Valium. Cocaine addicts' demand for heroin is inelastic, and alcohol is a complement to heroin while cocaine, marijuana and Valium are substitutes to heroin.

This paper contributes to prior literature in several ways. First, our experiments elicit drug addicts' preferences for drugs in settings that are difficult to study naturalistically. Second, we calculate elasticities controlling for age, gender and race. Third, we apply an econometric methodology that estimates a demand functional form in accordance with consumer theory. Fourth, our data has policy implications specifically related to polydrug use patterns.

2. Related Literature

Economic studies analyzing elasticities of licit and illicit drugs address two questions. They first examine the Becker-Murphy (1988) theory of rational addiction. If future variables have significant impact on current consumption, the theory of rational addiction cannot be rejected; such findings would be consistent with addicts anticipating future prices and adjusting use accordingly. The second question is what would happen if cocaine, marijuana, or heroin were legalized. To address this question, own price elasticities are estimated. To infer what would happen to other drug use if one is legalized, the signs of cross price elasticities are computed.

An advantage of focusing on drug dependent individuals is that findings obtained from general populations may not be representative of addicted populations. Drug-dependent individuals may demonstrate different patterns of drug use and different demand for drugs than recreational or infrequent users who are included in most economic studies. Economic variables may also differentially influence polydrug use patterns in these populations. Cocaine-dependent individuals, for example, may demonstrate different patterns of substitution than heroin-dependent individuals.

To obtain elasticities of interest, we choose the Almost Ideal Demand System proposed by Deaton and Muellbauer (1980a). While most alternative methods contradict basic principles of microeconomic demand theory, the Almost Ideal Demand System satisfies underlying assumptions of consumer behavior. To our knowledge, only Jones (1989) has applied this approach to the study of addiction. He estimates alternative models of demand for cigarettes and alcohol using budget share equations and concludes that addiction plays an important factor in smoking.

In the economic literature of addiction in general, the range of own price elasticities is surprisingly large and varies by drug, time frames over which prices change (short- vs. long-term), and population. Saffer and Chaloupka (1999a) estimate price elasticities of alcohol, cocaine and heroin to be –0.30, -0.28 and –0.94, respectively, using 1988, 1990 and 1991 National Household Surveys on Drug Abuse. Saffer and Chaloupka (1995) report price elasticities of -1.80 to -1.60 for heroin, and -1.10 to -0.72 for cocaine in another national sample of persons of all ages. Grossman and Chaloupka (1998) report the long-run price elasticity[2] of total consumption is -1.35 for youth.

Using percentage of arrestees testing positive for cocaine and heroin and assumptions about the relationship between drug use and the probability of arrest, Caulkins (1996) estimates price elasticities of demand of -2.50 for cocaine and -1.50 for heroin. In contrast, DiNardo (1993) finds that cocaine demand is irresponsive to price changes. Silverman and Spruill (1977) and van Ours (1995) report demand for heroin in Detroit and the short run demand of opium in Indonesia, respectively, to be inelastic. Liu et al. (1999) finds that the short and long price elasticities of opium in Taiwan between 1914 and 1942 were -0.48 and -1.38, respectively. Presumably, the long-term elasticities are more elastic because they assess effects of opium price among a wider range of individuals, including those who have not sampled the drug. As noted earlier, dependent and non-

[2] The long run elasticity takes into account both the long run effect on quantities consumed by current users due and the effect that price changes have on participation decisions of potential users.

dependent individuals may show different elasticities. Bretteville-Jensen and Sutton (1999) find price responsiveness of heroin to be -1.23 for non-dealing users and -0.20 for dealers who use.

Although fewer economic studies have examined cross price elasticities, Chaloupka, Grossman and Tauras' (1999) find that cocaine and marijuana are either complements or independents. Saffer and Chaloupka (1999b) note evidence of complementarity between heroin, cocaine, marijuana and alcohol, but marijuana substituted for alcohol. Studies in general populations tend to show complementarity between alcohol and illicit drugs (Saffer and Chaloupka 1999a, 1999b). Pacula (2001) finds that alcohol prices affect negatively marijuana demand (complementarity), but that cigarettes prices do not. Farrelly et al. (1999) maintains that marijuana, alcohol and tobacco are complements, and Dee (1999) shows a robust complementarity between alcohol and smoking. Pacula (1998a and 1998b) likewise finds alcohol and marijuana are complements. Decker et al. (2000) find that higher alcohol prices decrease smoking participation, but higher cigarette prices increase drinking. However, none of these studies have evaluated the cross-price elasticities exclusively in heavy using or dependent populations.

Thus, studies in general populations agree on the negative sign of own price elasticities and some cross price elasticities, but they differ in the range of the estimates. The range is so large that the question arises as to the cause of such diversity: source of information, specification of the model, or the empirical methods. As Hunt et al. (1994) suggests, the lack of attention to the relation between theory and estimation makes discerning the cause of the diversity difficult.

Attempts to understand the economic relationships between drugs have also been made by psychologists, primarily using laboratory paradigms. In these studies, drug-experienced subjects press levers to obtain access to drugs as the number of lever presses is altered as a proxy of price. In terms of own-price elasticities, demand for alcohol is more inelastic than demand for sucrose in rats with extensive alcohol histories (Petry and Heyman, 1995), and laboratory studies with human smokers find similar elasticities for nicotine as reported in the economic literature (e.g., Bickel et al., 1991). With respect to cross-price elasticities, Bickel et al. (1995) review 16 studies in which two reinforcers, one or both of which were drugs, were concurrently available and prices varied systematically. Some drugs are substitutes for others (alcohol was a substitute for PCP; Carroll, 1987), some serve as complements (cigarettes are a complement to heroin; Mello et al., 1980), and others are independent (cigarette use is independent of alcohol prices; Mello, 1987).

Although relationships between drug prices and consumption could be studied in the laboratory by providing drugs to participants, logistical and ethical considerations exist. Hypothetical behavioral experiments involve simulation of essential aspects of a situation to elicit the behavior in question (Epstein, 1986). The methods are used in experimental economics such that resultant data are predictive of real-world behavior (Plott, 1986). Recently, a paradigm was developed to apply economic analyses to the phenomenon of polydrug abuse. Drug abusers are given imitation money, and prices of drugs are indicated on paper. Subjects state the types and quantities of drugs they would buy, presuming they had the available incomes. Changes in drug choices are examined as a function of prices. A study with heroin addicts (Petry & Bickel, 1998a) finds that cocaine is a complement to heroin. In addition, Valium is a substitute for heroin, but this relationship is not symmetrical; price of Valium has no effect on purchases of heroin in heroin addicts. A second study with alcoholics (Petry, 2001a) finds that cocaine is a complement to alcohol, but alcohol is a substitute for cocaine. Demand for all other drugs is independent of both alcohol and cocaine prices. These studies evaluated how changes in drug purchases affected consumption patterns, without controlling for social demographic variables.

The purpose of this study is to replicate and methodologically improve the above findings by integrating the psychological (laboratory paradigm based) and economic (econometric based) approaches. We examine effects of heroin and cocaine prices on preferences for heroin, cocaine, alcohol, marijuana, Valium and cigarettes. Both heroin and cocaine addicts are tested to assess whether the relationships between drug prices and consumption varies between the two groups.

3. Data and design

Here, we describe our data, experimental design, recruitment strategy, and summary of characteristics.

3.1 Data

Our data were collected from two experiments run simultaneously. A total of 81 subjects participated, and they were recruited using newspaper advertisements and flyers at low-income housing projects and social service agencies in the Hartford, CT, area. A telephone screen assessed eligibility criteria, which included Diagnostic and Statistical Manual IV (American Psychiatric Association, 1994) criteria for heroin or cocaine dependence, age 18 or older, and English speaking. Subjects were categorized into their "hardest" drug of abuse, with heroin considered a harder drug than cocaine. Thus, subjects meeting criteria for heroin dependence were classified as "heroin addicts," even if they were dependent on other drugs, including cocaine. "Cocaine addicts" included subjects meeting cocaine dependence criteria with or without other dependencies, with the exception of heroin. A structured interview assessed lifetime abuse histories. Subjects also provided a breath sample that was screened for alcohol and a urine specimen that was screened for recent use of opiates, cocaine, and marijuana[3]. Subjects provided written informed consent and received $50 for participation. Those not in substance abuse treatment were referred for treatment.

TABLE 1

Table 1 shows demographic and drug use characteristics for the two groups. Gender, racial, and martial status are similar, but income was lower in heroin addicts than in cocaine addicts. Drug use histories were similar between groups except that heroin addicts use more heroin and benzodiazepines than cocaine addicts. Heroin addicts also had more legal problems.

Social demographic characteristics of our sample are very similar to larger sample addict populations. From a nationally representative sample of 1,799 addicts in treatment between 1988 and 1990, SROS-SAMHSA (1998) reports that 71.4% were male, 60.1% white, 28.4% black, 8.2% Hispanic, with a range of years of age, education, and marital and legal status similar to our sample.

Design

This subsection describes the design of the experiments, in which various drugs, in amounts typically used for a "hit" were presented on a piece of paper. Initial prices for each drug were representative of Hartford, CT, street prices as determined by informal survey. In Experiment 1,

[3]The breathalyzer was an Alcosensor by IV Alcometer (Intoximeters, St. Louis). The urinalysis was done with an

price of heroin varied from $3, $6, $15 and $30 per bag, while all other drugs remained at their street prices. In Experiment 2, price of cocaine varied from $2, $4, $10 and $20 per eighth gram.

Drug	**Quantity**	**Street Price**	**Price Variations**
Heroin	1 bag	$15	$3, $6, $15 and $30
Cocaine	$\frac{1}{8}$ gram	$10	$2, $4, $10 and $20
Marijuana	1 joint	$5	
Alcohol	1 drink	$1	
Valium	1 pill	$1	
Cigarettes	1 pack	$2	

The experimenter read instructions (Appendix 1) and handed subjects $35 of imitation money. The two experiments were conducted concurrently, and the order of conditions was randomized for each subject. Subjects had to allocate their budgets to purchase their ideal consumption basket, given the prices faced. They were presented 8 different price situations generating a total of 648 observations. Since some participants did not choose to spend the entire budget for drugs, we assume that undesired purchases were not made. Nevertheless, participants could not carry over any amount towards purchases in the next experiment.

TABLE 2

Table 2 reports participants' drug choices when faced with different heroin and cocaine price combinations. Tables on the left panel describe heroin choices by heroin addicts, and tables on the right panel heroin choices by cocaine addicts. The first two columns of the tables in Table 2 contain heroin and cocaine price combinations presented to participants. For each combination, we report the frequency with which participants bought each number of drug *units*, i.e., two heroin addicted participants did not buy any heroin at all when the price of a bag of heroin was $3 and 1/8 gram of cocaine was $10, while 3 participants decided to buy 11 bags of heroin. Tables 2.3-2.4, 2.5-2.6, 2.7-2.8, 2.9-2.10, and 2.11-2.12 report choices for cocaine, marijuana, alcohol, Valium and cigarettes, respectively. The bottom row of each table reports total amounts of units purchased, and the last cell shows the grand total of units purchased at any price. From looking at the grand totals of Table 2, we observe that heroin addicts consume more than ten times the quantity of heroin than

EZScreen (Editek, Inc., Burlington, NC).

cocaine addicts do (723 as opposed to 65); cocaine addicts consume about five times more cocaine than heroin addicts (1138 as opposed to 213); heroin addicts consume more marijuana joints (111 as opposed to 72); less alcohol (931 as opposed to 1575); twice the amount of Valium (103 as opposed to 43); and fewer packages of cigarettes (654 as opposed to 954).

As an indicator of the quality of our experimental data, we calculate Spearman correlations[4] between experimental choices and years of regular use of each drug as shown in table 3.

TABLE 3

The number of units of each drug purchased in the simulation is significantly correlated with years of lifetime regular use for each drug. Table 3 also presents point biserial correlations[5] of experimental choices and objective indicators of recent use of heroin and marijuana, as assessed by urinalysis. These correlations are positive and significant for heroin and marijuana, significant at the 92% level for alcohol, and not significant for cocaine. In sum, Table 3 shows that choices made in the experiment are consistent with real life drug use. Therefore, we assume that this is a valid sample of drug addicts to infer illegal drug own and cross price elasticities. In the next section, we describe the econometric specification we use to measure these elasticities.

4. Econometric Specification

First, we provide the demand system specification used to estimate own and cross price elasticities. Next, we explain how demand system coefficients estimate the elasticities of interest.

The demand of a good equals the aggregate demand of all individuals who constitute the market for that good. Each individual's demand is derived from the decision process of maximizing utility subject to a budget constraint. Assuming an arbitrary aggregate demand function is not innocuous, a particular functional form may impose restrictions on the underlying consumer utility and expenditure functions. Log-linear and linear specifications of the demand for a good are often chosen for their simplicity but may violate the principle that consumers cannot spend more than they have (see Hunt et al. (1994) and Stern (1986) for a detailed discussion of these specifications).

[4] Because of the non-normality of both drug choices and years of use, their correlation is assessed using Spearman correlations.
[5] The correlations between positive objective drug use (from urinalysis and breathalyzer readings) and the choices of drugs are calculated using point biserial correlations because the objective drug use measure is dichotomous.

We estimate cross price elasticities of drugs using the demand functional form proposed by Deaton and Muellbauer (1980a) known as the Almost Ideal Demand System. This system gives an arbitrary first-order approximation to any demand system that is consistent with the notion of scarcity (by which individuals are forced to make choices) and satisfies the axioms of individual choice. Besides applying a new methodology for the estimation of price elasticity, our specification also controls for age, gender, education, health and employment status.

Deaton and Muellbauer propose this equation for budget share of the *i*-th good of household *l:*[6]

$$w_{il} = \alpha_i + \sum_{j=1}^{n} \gamma_{ji} \ln p_j + \beta_i \ln\left(\frac{C_l}{P_l}\right) + \delta_i Z_l + \varepsilon_{il}\,, \qquad (1)$$

where p_i is the price of good *i*; C_l/P_l is the total *real* expenditure on all (*n*) goods in the consumer's budget; P_l is a price index; Z_{il} is a set of exogeneous variables describing the individual -or household- *l* characteristics; and ε_{il} is individual *l*'s idiosyncratic taste for drug *i*.

For a demand system to be in accordance to the properties of demand functions known as adding up, homogeneity and symmetry, the estimated parameters must satisfy these restrictions:

Adding up: $\Sigma_i\alpha_i=1,\ \Sigma_i\gamma_{ij}=0,\ \Sigma_i\beta_i=0,\ \Sigma_i\delta_i=0 \quad \forall i,j$ (2)

Homogeneity: $\Sigma^n_{j=1}\ \gamma_{ij}=0 \quad \forall i$ (3)

Symmetry: $\gamma_{ij}=\gamma_{ji} \quad \forall i,j$ (4)

The restriction of *adding-up* ensures that the parameters estimated are compatible with the fact that the sum of purchases on all goods has to be equal to their budget ($\sum_i w_i=1$). The restriction of *homogeneity* guarantees that the underlying demand is homogeneous of degree zero in prices and total expenditure taken together (i.e., if prices and income are multiplied by the same positive number, the quantities purchased are unaffected). Finally, equation 4 guarantees the *Slutsky symmetry* condition, e.g., cross-price responses of any pair of goods are equal when price changes are compensated by equivalent income changes so that the real income (and utility) remains intact.

We assume that the utility of drugs is weakly separable from the quantities consumed for all other goods.[7] This is consistent with the study design where the budget given to the participants

[6] The budget share is the fraction of the individuals total expenditure that is spent on good *i:* $w_i=(p_iq_i/ y)$, where q_i is the quantity of good *i* purchased, p_i its price, and *y* the individual's total expenditure.

was to be spent on drugs, assuming that the fraction of income assigned to all other goods is decided in another decision stage. We consider the second stage of a two stage budgeting process when consumers decide how much of the drug budget they allocate among different drugs, given their relative prices. Adapting the Almost Ideal Demand System in equation (1) to our setting, the budget share of heroin, cocaine, marijuana, alcohol, Valium, and cigarettes are given by:

$$w^t{}_{hl} = \alpha_h + \sum_{j=1}^{n} \gamma_{jh} \ln p^t{}_j + \beta_h \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_h Z_l + \varepsilon^t{}_{hl} \qquad (5)$$

$$w^t{}_{cl} = \alpha_c + \sum_{j=1}^{n} \gamma_{jc} \ln p^t{}_j + \beta_c \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_c Z_l + \varepsilon^t{}_{cl} \qquad (6)$$

$$w^t{}_{ml} = \alpha_m + \sum_{j=1}^{n} \gamma_{jm} \ln p^t{}_j + \beta_m \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_m Z_l + \varepsilon^t{}_{ml} \qquad (7)$$

$$w^t{}_{al} = \alpha_a + \sum_{j=1}^{n} \gamma_{ja} \ln p^t{}_j + \beta_a \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_a Z_l + \varepsilon^t{}_{al} \qquad (8)$$

$$w^t{}_{vl} = \alpha_v + \sum_{j=1}^{n} \gamma_{jv} \ln p^t{}_j + \beta_v \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_v Z_l + \varepsilon^t{}_{vl} \qquad (9)$$

$$w^t{}_{tl} = \alpha_t + \sum_{j=1}^{n} \gamma_{jt} \ln p^t{}_j + \beta_t \ln\left(\frac{C^t{}_l}{P^t{}_l}\right) + \delta_t Z_l + \varepsilon^t{}_{tl} \qquad (10),$$

where subscripts *h,c,m,a,v,c* stand for *heroin, cocaine, marijuana, alcohol, Valium,* and *cigarettes*; subscript *l* stands for the l^{th} individual, and superscript *t* stands for the t^{th} price setting, and the rest of variables are defined as for equation (1). For simplicity, from now on we suppress the *t* superscript. Given the nature of our experiment, instead of using total real income, C_l/P_l, as described in (1), we have to use total expenditure on drugs, i.e., $C_l = q_{lh}P_h + q_{lc}P_c + q_{lm}P_m + q_{la}P_a + {}$ $+ q_{lv}P_v + q_{lt}P_t$. The logarithm of the index of prices P_l is obtained using the Stone linear approximation, i.e. by weighting the logarithm of each price by the mean share of each drug in individual's *l* budget: $\ln P_l = w_{lh}\ln P_h + w_{lc}\ln P_c + w_{lm}\ln P_m + w_{la}\ln P_a + w_{lv}\ln P_v + w_{lt}\ln P_t$. The social demographic variables included in Z_l are: gender, being white or not, years of age, years of education, an indicator of employment problems and an indicator of medical problems.[8]

[7] Nevertheless, and as mentioned earlier, using the Almost Ideal Demand System ensures that our addictive substances demand system is consistent with a one stage procedure, see Deaton and Muellbauer (1980b).
[8] The employment and medical problems indicators are based on answers to employment and health related questions, for more details about their construction see McLellan (1988). Although the weighting system used to obtain them is arguable, these severity indices are positively correlated with employment and medical problems and we use them as

Once parameters in equations (5-10) are estimated, own and cross price elasticities are calculated:

$$\varepsilon_{ii} = \frac{\gamma_{ii}}{w_i} - \beta_i - 1 \quad (own - price \quad elasticity\ : i^{th}\ good) \qquad (11)$$

$$\varepsilon_{ij} = \frac{\gamma_{ij}}{w_i} - \beta_i \frac{w_j}{w_i} \quad (cross - price \quad elasticity\ : i^{th}\ good \quad with \quad respect \quad to \quad j^{th} \quad good - price) \quad (12)$$

Following Deaton and Muellbauer (1980a), first, we estimate the demand system, equations (5) to (10), without restrictions (3) and (4). By construction, the *unconstrained* estimated coefficients do satisfy the *adding-up* constraints since the expenditure shares in drugs sum up to 1. Second, we test if the *unconstrained* coefficients satisfy the *homogeneity* constraint, equation (3), and the *symmetry* constraint, equation (4).[9] Additionally, we estimate equations (5) to (10) subject to the homogeneity and symmetry constraints, i.e., subject to equations (3) and (4). We call these estimates *constrained.* Elasticities in (11) and (12) are then calculated using the estimated parameters and individual sample budget share means.[10]

The next section reports the results of the estimation, and the limitations of the estimates.

5. Results

In this section, we present the estimates for equations (5) to (10). The system of equations is estimated by using generalized least squares to account for the error correlation structure across equations. We use White-corrected standard errors, which control for the fact that we have repeated observations on individuals. In the next part, we report on own and cross price elasticities.

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proxies for real employment and health problems. Although medical and employment problems are potentially endogenous variables in the system, specifications where they were not included did not alter significantly the results. Therefore, we report the specification that includes these two variables.

[9] Although due to the nature and design of the experiment there might exist data censoring issues, we choose not to correct for those as have done other published applications using the Almost Ideal System.

[10] Assuming that the mean budget shares are independent across individuals, the variances of the own-price and cross-price elasticities have been obtained by using the formulae:

$$Var\left(\frac{\sum_{l=1}^{N} \varepsilon_{ii}{}^{l}}{N}\right) = \frac{1}{N^2} Var\left(\sum_{l=1}^{N} \varepsilon_{ii}{}^{l}\right) = \frac{1}{N^2} \sum_{l=1}^{N} \left(Var(\beta_i) + \frac{Var(\gamma_{ii})}{w^2{}_{il}} - \frac{2\operatorname{cov}(\beta_i, \gamma_{ii})}{w_{il}} \right)$$

$$Var\left(\frac{\sum_{l=1}^{N} \varepsilon_{ij}{}^{l}}{N}\right) = \frac{1}{N^2} Var\left(\sum_{l=1}^{N} \varepsilon_{ij}{}^{l}\right) = \frac{1}{N^2} \sum_{l=1}^{N} \left(\frac{1}{w^2{}_{il}} [w^2{}_{jl} Var(\beta_i) + Var(\gamma_{ij}) - 2 w_{jl} \operatorname{cov}(\beta_i, \gamma_{ij})] \right)$$

where $\varepsilon_{ii}{}^{l}$ and $\varepsilon_{ij}{}^{l}$ indicate individual *l* own-price elasticity for good *i* and cross-price elasticity for good *i* with respect to changes in prices of good *j*; budget share w_{lk} indicates individual *l*'s sample mean budget share for good *k*, and coefficients β and γ correspond to the estimates obtained by taking equations (2) and (3) to the data.

The estimates for the demand system of heroin addicts are reported in table 4, and those of cocaine addicts in table 5. Tables 4 and 5 report three sets of coefficients for each drug: The first column contains what we call *unconstrained* coefficients, i.e., estimated without imposing the symmetry and the homogeneity restrictions, although it should be noted that the adding up restriction is satisfied by construction. The second column contains the *constrained* coefficients obtained by simultaneously estimating heroin, cocaine, marijuana, alcohol and Valium demand equations subject to the homogeneity and the symmetry constraints. The cigarette demand equation is not included because, due to the *adding-up* restriction, the covariance matrix is singular and the likelihood function undefined, i.e., one of the demand equations is redundant and the elasticities can be calculated without estimating it. At the end of tables 4 and 5, we report the R squared. The p-value at the bottom compares the estimated model a model in which all coefficients are restricted to be zero. This test is distributed as a $F(k\text{-}1,n)$, where k is the number of regressors included, l the number of restrictions when applicable, and n the number of observations.

The *homogeneity* and the *symmetry* tests on the *unconstrained* model coefficients test if these estimates satisfy equations (3) and (4), respectively. To test the *homogeneity* constraint we test whether the sum of the coefficients of the log of the prices of heroin and cocaine sum up to zero for each equation. Each of statistics tests follows a χ^2 probability distribution with 1 degree of freedom. To test the *symmetry* constraint we have to test whether the sum of the coefficients corresponding to the log of the price of cocaine in the heroin equation and the coefficient of the log of the price of heroin in the cocaine equation is zero, and reciprocally, that the sum of the heroin equation's coefficient for the log of the price of cocaine and the coefficient for the log of the price of heroin in the cocaine equation is zero. Each of these statistics follows a χ^2 probability distribution with 1 degree of freedom.

In the next few paragraphs we discuss the effects of the demographic characteristics on the demand of the various drugs, as reported in Tables 4 and 5. Since heroin and cocaine price coefficients in equations (5) to (10) cannot be interpreted as price elasticities, we analyze heroin and cocaine price effects on each drug demand using the elasticity estimates reported in Table 6.

Social Demographic Characteristics:

The effect of years of age, education, race, employment and health problems on the demand of the different drugs can be analyzed looking at the coefficients reported in Tables 4 and 5. Looking at the *constrained* model, we observe that, for heroin addicts, the effect of *age* is not significant for any drug. Being *male* increases the use of *alcohol*. *Whites* buy relatively more alcohol than non-whites. Years of *education* influence positively the purchases of heroin and Valium. Heroin addicts with more *employment problems* tend to use more heroin but less cocaine and alcohol. More *health problems* are associated with lower *cocaine* purchases. In the *constrained* specification for cocaine addicts, years of *age* and being *white* affect positively the use of *valium*. *Health problems* are associated with higher heroin consumption.

In the *unconstrained* model, and for heroin addicts, being *male* positively affects use of alcohol and negatively that of Valium. Being *white* affects positively the consumption of alcohol. Years of *education* have a positive effect on heroin and Valium purchases. *Employment problems* are associated positively to heroin consumption, and negatively to that of cocaine and alcohol. Finally, *health problems* are associated with less cocaine. For cocaine addicts, *age* and being *white* affect positively purchases of Valium, and *health problems* relate to heroin use.

With respect to the variable *real expenditure,* we observe that, for heroin addicts, its sign is significant and negative in both specifications of the heroin demand, and positive and significant for both specifications for the demand of alcohol. Thus, for heroin addicts, an increase in the individual purchasing power due to changes in prices decreases heroin's budget share and increases that of alcohol, which means that heroin is an *inferior* good where, for these individuals, alcohol could be considered a *luxury* good. The inferiority of illegal drugs has been documented in the literature. Roy (2005) provides a good summary of the existing evidence.

For cocaine addicts, real expenditure has a *negative* coefficient for both specifications of demand of heroin and marijuana, a *negative* coefficient for the unconstrained specification for cocaine, and a *positive* coefficient for both specifications of the demand for alcohol. Thus, for cocaine addicts, heroin, cocaine and marijuana are *inferior* goods and alcohol a *luxury* good.

Homogeneity test: Taking a look at the homogeneity test on the coefficients of the *unconstrained* model specification in Tables 4 and 5, we observe that all but the cocaine and marijuana equations do not reject the null hypothesis of homogeneity for heroin addicts. For cocaine addicts, all equations but that of Valium do not reject the homogeneity null hypothesis.

Symmetry test: The symmetry test on the null hypothesis described in equation (4) is not rejected for both the heroin addicts and the cocaine addicts. The fact that both tests are rejected so infrequently may partially explain why some coefficients are so similar in both specifications. Also, note that even if for a particular drug the *unconstrained* coefficients do not satisfy the *homogeneity* and *symmetry* conditions, they always satisfy the *adding-up* restriction. Therefore, the generating demand satisfies that there is *no free lunch*. Even if not optimal, the elasticities obtained using these coefficients present advantages with respect to previously obtained values.

Next, we discuss effects of heroin and cocaine price changes on demand of all drugs in terms of own and cross price elasticities. These elasticities are calculated using equations (11) and (12) and the estimates of the demand system in equations (5) to (10). Table 6 summarizes the own and cross price elasticities of heroin, cocaine, marijuana, alcohol, Valium and cigarettes with respect to changes in heroin and cocaine prices, for heroin addicts and cocaine addicts separately.

TABLE 6

We complement the explanation of effects of heroin and cocaine prices on the demand of the different drugs as reported in Table 6 with figures. These figures plot the average purchases of drugs as a function of heroin and cocaine prices. Note that figures are based on unconditional average purchases while elasticities in Table 6 are obtained controlling by age, education, etc.

Experiment 1: Heroin price changes

Figure 1 shows heroin average purchases as a function of its price in Experiment 1. Data from heroin addicts are shown in open symbols and data from cocaine addicts in filled symbols. As expected, on average heroin addicts purchase greater quantities of heroin than cocaine addicts, and in both groups the number of average purchases decreases as price of heroin increases.

FIGURE 1

Heroin own price elasticity: In table 6, we observe that the unconstrained model heroin own-price elasticity for both samples is similar and between -0.917 (heroin addicts) and -0.913 (cocaine addicts), being lower when the homogeneity and symmetry conditions are imposed (-0.818 heroin addicts, -0.882 cocaine addicts).

TABLE 6

Heroin cross price elasticities: The effects of heroin price changes on all other drug purchases except for heroin are shown in Figure 2. The effects of heroin price changes in heroin addicts' average purchases appear in the top panel of the figure, and the effects in cocaine addicts' average purchases appear in the bottom panel.

FIGURE 2

In table 6 we see that among heroin addicts, the price of heroin influences the purchases of cocaine, marijuana, Valium, alcohol and cigarettes. Looking at the *unconstrained* coefficients, we observe that for heroin addicts cocaine (-0.182), marijuana (-0.055) and alcohol (-0.289) are complements where Valium (0.067) and cigarettes (0.242) are substitutes. The *constrained* specification leads to similar results although for that specification alcohol is a stronger complement (-0.792) and Valium becomes a complement (-0.034).

For cocaine addicts, according to the *unconstrained* model, cocaine (0.189), marijuana (0.100), and Valium (0.015) are substitutes for heroin, and alcohol (-1.586) is a complement. The *constrained* specification leads similar qualitative results.

Experiment 2: Cocaine prices changes

Figure 3 shows cocaine average purchases as a function of its price in Experiment 2.

FIGURE 3

Cocaine own price elasticity: Table 6 shows price of cocaine significantly affects cocaine purchases in both heroin and cocaine addicts. Demand for cocaine is inelastic in heroin addicts with estimates close to -0.9 (-0.902 *unconstrained*, -0.892 *constrained*). For cocaine addicts, demand for cocaine has a negative slope in both specifications but it is elastic (-1.051) in the un*constrained* specification and -0.896 in the *constrained* one.

Cocaine cross price elasticities: Figure 4 shows purchases of other drugs as a function of cocaine prices. In heroin addicts (top panel), according to both the *unconstrained* and *constrained* model, marijuana (0.091 and 0.224) and Valium (0.090 and 0.043, respectively) are substitutes for cocaine, while alcohol (-0.384 and -0.635), and cigarettes only in *constrained* specification, -0.274 are a complement.

In cocaine addicts, heroin is a complement to cocaine according to the *unconstrained* specification (-0.051) and a substitute in the *constrained* one (0.057), alcohol is a complement to cocaine according to both models (-0.057 and -0.941), while marijuana (0.052 and 0.090) and Valium (0.006 and 0.011) are substitutes.

FIGURE 4

Limitations:

Results from this study must be interpreted in light of several additional limitations. First of all, choices in this procedure are hypothetical, and they may not be consistent with real-world drug use patterns. Whether substance abusers actually would choose these same types and amounts of drugs in natural settings is not known. Drug preferences were evaluated over large changes in price conditions that may or may not be analogous to how drug prices change on the streets. Two- to three-fold increases in prices were used to evaluate preferences under extreme conditions. Similarly, prices for illicit drugs also can vary markedly from day to day in real-world settings (e.g., when a large shipment comes in compared to after a police raid). Nevertheless, whether smaller changes in price engender similar effects could be a topic worth studying.

This study evaluated only short-term effects with respect to own and cross-price elasticities. The present study imposed a one-day temporal frame on purchasing decisions because we, and others, have shown that substance abusers have a significantly truncated time horizon (Brettenville-Jensen et al., 1999; Kirby et al., 1999; Petry and Casarrella, 1999; Vuchinich and Simpson, 1998).

Therefore, hypothetical decisions made over longer time intervals may be less valid. The use of a constant temporal frame, however, may have the drawback of not reflecting the manner in which decisions are made in real-world situations. Nevertheless, as predicted by the *rational addiction theory* (Becker and Murphy, 1988), individuals' long-run elasticities tend to be larger than short-run elasticities. Secondly, long-run effects of price changes affect not only current users but also participation decisions of potential ones. Thus, the elasticities reported could safely be considered a *lower-bound* of the long-run elasticities, probably more relevant for policy making decisions.

Other factors, including moods, social contexts, and fear of legal recourse, also may affect choices for drugs, but these variables were not evaluated in the present study. Future research may address the influence of these and other factors and how they may interact with economic variables in influencing drug use (see also Glautier, 1998; Reuter, 1998).

6. Policy Implications

Taking the *unconstrained* model estimates as the relevant ones there are some relevant policy implications of our results. First, heroin addicts are big consumers of heroin, and they also use substantial amounts of cocaine (see table 2). For heroin addicts, cocaine is a complement to heroin, and increases in heroin prices reduce their heroin as well as their cocaine consumption. For cocaine addicts, heroin prices do affect both heroin negatively and cocaine positively as cocaine is a substitute to heroin for this group. Therefore, *heroin price increases* will reduce heroin and cocaine addicts' heroin consumption; but, while heroin addicts' cocaine consumption will be reduced, cocaine addicts' cocaine consumption will be increased. An increase in the price of cocaine will, on the other hand, reduce heroin and cocaine addicts' cocaine consumption and -very moderately- cocaine addicts' heroin consumption. Taking all these considerations together it seems that it may be more efficient to pay special attention to cocaine-price increasing policies rather than to heroin-price increasing policies. The reason is that the former will reduce heroin and cocaine consumption by both types of addicts while the latter will have ambiguous effects by increasing cocaine addicts' cocaine consumption.

From a policy point of view, an important implication of the fact that cocaine and heroin are found to be *inferior goods* is that income redistributive policies may help alleviate the problem of substance abuse, as indicated by Roy (2005).

Finally, our results indicate that policies that increase prices of heroin may create greater addiction to Valium and cigarettes for heroin addicts, and to cocaine, marijuana and Valium for cocaine addicts. Similarly, policies that increase the price of cocaine may induce greater addiction to marijuana and Valium for both types of addicts. To put in place compensatory policies to alleviate the spill-over addictive effects of increasing heroin and cocaine prices would seem advisable.

7. Summary and conclusions

Illicit drug users often abuse a wide variety of drugs. Polydrug use presents an enigma to both medical treatment providers and economists trying to predict the consequences of drug policies. We utilize an experimental method to provide information to psychologists about how drug prices may influence polydrug use patterns controlling for other than price influential factors, and to economists about how price-affecting policies may affect addicts' drug use and their welfare.

We study polydrug use patterns in heroin and cocaine addicts using two experiments that vary heroin and cocaine prices. We obtain own price elasticities of heroin and cocaine, and cross price elasticities of these and other drugs when heroin and cocaine prices vary. We apply an econometric methodology that estimates a demand functional form in accordance with consumer theory. Additionally, this paper illustrates how a particular demand function specification may influence the value of the elasticities obtained. As an innovation with respect to the illicit drug elasticities obtained in experimental settings, we control for other sources of variation besides the change of prices by including demographic factors in our elasticities' estimation method. Traditionally, the psychological literature has not controlled for demographics in estimating elasticities. Generally, both methods produce similar results, although the econometric analysis finds significant effects of drug prices on larger selections of drugs.

We find that heroin addicts show an inelastic demand for both heroin (-0.917) and cocaine (–0.902). Meanwhile, cocaine addicts' seem more responsive to prices. For this group, cocaine demand is very much affected by cocaine price changes (-1.051), but their heroin demand is inelastic (-0.913). Heroin addicts seem to complement their heroin consumption with cocaine, marijuana and alcohol, but substitute it with Valium and cigarettes. Heroin addicts substitute their cocaine consumption with marijuana and Valium and complement it with alcohol. Cocaine addicts behave slightly differently and substitute heroin intake with cocaine, marijuana and Valium, and complement it with alcohol. Cocaine addicts complement cocaine consumption with heroin and alcohol and substitute it with marijuana and Valium.

Taken together, these results suggest that heroin and cocaine addicts show differential demands for drugs depending on the prices of heroin and cocaine, and these effects are not always symmetrical. Heroin is a complement to cocaine for heroin addicts but cocaine prices seem not to affect their heroin's consumption. In contrast, cocaine addicts substitute cocaine for heroin when heroin prices increase but, at the same time complement their cocaine intake with heroin. Heroin addicts have a significantly inelastic demand for heroin and cocaine, while cocaine addicts have an elastic demand (-1.051) for cocaine and an inelastic demand for heroin. Valium is a substitute for heroin and cocaine for heroin addicts, but a much weaker substitute for heroin and cocaine in cocaine addicts. Nevertheless, alcohol seems to be a complement to heroin for both types of addicts but its consumption is much more affected by heroin prices for cocaine addicts. Finally, marijuana is a complement to heroin for heroin addicts and a substitute for cocaine addicts.

Our results are validated from different perspectives: First, drug choices in the simulation are correlated with lifetime drug abuse histories as well as objective indicators of recent drug use and three previous studies (Petry, 2000, 2001a; Petry and Bickel, 1998b). Second, subjects are exposed to the same price conditions twice to assess reliability of choices. Test-retest reliability correlations indicate good reliability between repeat exposures, ranging from 0.44 to 1.0 across studies (Petry, 2000, 2001a, 2001b; Petry and Bickel, 1998a). Third, our results are consistent with both economic and clinical findings. Elasticities obtained from this paradigm lie comfortably in the range of elasticities found in the literature. As expected, heroin and cocaine addicts seem to have a more inelastic demand for both heroin and cocaine than general populations. The finding that marijuana use decreases as heroin prices increases seems consistent with evidence in economic research (Saffer and Chaloupka, 1999b). Clinically, heroin addicts frequently use cocaine and heroin simultaneously, in a drug combination known as a "speedball." The complementary relationship between heroin and cocaine seems congruent with this use pattern in natural settings. Valium abates opioid withdrawal symptoms in treatment settings (Green and Jaffee, 1977; Woods et al., 1987), and the finding that Valium is a substitute for heroin is consistent with clinical data.

Cocaine addicts, who by definition were not dependent upon heroin, purchase far less heroin than heroin addicts in this simulation procedure. That alcohol is a complement to cocaine in cocaine addicts is also consistent with clinical and physiological data. Cocaine and alcohol interact to produce coca-ethalyene, a metabolite that has reinforcing effects of its own (McCance-Katz, et al., 1993) and reduces the crash associated with cessation of cocaine use (Gawin and Kleber, 1986).

This work illustrates that controlled experiments may provide useful information about preferences for combinations of licit and illicit drugs in a difficult to study group. The use of this paradigm may aid in better understanding how drug users complement and substitute their main addiction(s) as drugs' prices change. These data show how prices of heroin and cocaine influence drug use patterns differently in two distinct groups of drug addicts. Just as the two drug dependent populations show distinct patterns, non-dependent samples are likely to demonstrate even more disparate drug use patterns in response to price changes. Recreational users may show different patterns compared to individuals who have never sampled illicit drugs. That is precisely why our results are important. The more we know about how populations complement and substitute their addictions, the better we can design and calibrate drug policies and health care initiatives.

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APPENDIX 1:

STUDY INSTRUCTIONS

"*These next questions are to find out your choices for drugs across changes in prices. This information is entirely for research purposes. We're going to use this sheet and fake money to play a type of game. Please answer the questions honestly and thoughtfully:*

Assume you have access to $35 a day that you can buy drugs with (The experimenter handed the subject the imitation money).

The drugs you may buy and their prices are listed on this sheet (The experimenter pointed to the price sheet).

You may buy any drugs you'd like with this money, and there are no consequences to using these drugs. So, assume this is a study that has been approved by the police and all other organizations.

Also, assume that the only drugs you will receive are those you purchase with the allotted $35 per day. You have no other drugs available to you. You cannot purchase more drugs, or any other drugs except those you choose below. Therefore, assume you have no other drugs stashed away, you have no prescriptions for anything (including antabuse, naltrexone, methadone or Valium), and you cannot get drugs through any other source, other than those you buy with your $35 per day.

Also, assume that the drugs you are about to purchase are for your consumption only. In other words, you can't sell them or give them to anyone else. You also can't save up any drugs you buy and use them another day. Everything you buy is, therefore, for your own personal consumption within a 24-hour period.

With this $___, please indicate what you would purchase, and I'm going to check off each drug as you buy it so you'll know what you've purchased."

Table 1: Socio Demographic Characteristics

	Heroin Addicts	Cocaine Addicts
Observations	41	40
Male	63%	73%
Race	0%	0%
Caucasian	42%	38%
African American	32%	48%
Hispanic	24%	12%
Native American	2%	2%
Years Age	38 (7)	40 (7)
Years of education	12 (2)	13 (2)
Annual Legal Income	$5155	$7034
	($5772)	($9867)
Marital Status		
Married	8%	17%
Remarried	5%	2%
Widowed	5%	
Separated	8%	10%
Divorced	23%	12%
Never Married	53%	59%
Housing		
Homeless	43%	59%
Days homeless	108	292
	(219)	(533)
Living in shelter	38%	54%

	Heroin Addicts	Cocaine Addicts
Observations	41	40
Lifetime Abuse or dependence		
Heroin	100%	25%
Cocaine	83%	100%
Alcohol	80%	80%
Marijuana	76%	72%
Benzodiazepines	29%	15%
Breath or urine sample positive		
Opioids	50%	0%
Cocaine	50%	48%
Alcohol	3%	3%
Marijuana	30%	15%
History of intravenous drug ι	78%	18%
Legal Problems		
Awaiting Trial	23%	10%
Days of Illegal Activiti	3.25	1.04
	(8)	(3.5)
Illegal Money	$ 244	$ 32
	($915)	($158)

Numbers in parenthesis are standard deviations.

Table 2: Summary of the consumption patterns of alcohol, Valium and cigarettes at various prices

		heroin addicts																							Grand Total
prices ($)		number of alcohol drinks																							
heroin	cocaine	0	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	19	20	27	29	31	33	
3	10	24	1	1	5	1	3		3		1		1							1					
6	10	25		1	6	1	3	1	1			1						1			1				
15	10	22		3	7	2	3		1					1				1						1	
30	10	23		3	6	1	2		1				1	2				1						1	
15	2	26	2	2	4		2			1				1	1		1						1		
15	4	26	1	2	4	1	2		1			1			1				1			1			
15	10	22		3	7	2	3		1					1				1						1	
15	20	23		1	5	5	3	1						1				1						1	
Total:			4	32	132	52	105	12	64	9	10	22	24	78	28	0	16	85	19	20	27	29	31	132	931

		cocaine addicts																				Grand Total
prices ($)		number of alcohol drinks																				
heroin	cocaine	0	1	2	3	4	5	6	7	8	10	11	12	13	14	15	20	25	30	33	35	
3	10	16	1	3	9	1	2		1		3		2				1	1				
6	10	14	2	2	6	2	4		1		4		2	1			1				1	
15	10	15	2	1	7	3	3			1	4		1				1	1			1	
30	10	14	2	1	6	3	4			1	5		1	1			1				1	
15	2	13	6		5	2	5	1	2	1	2		1					1		1		
15	4	13	5	1	5		4	4	1	1	2		1			1	1				1	
15	10	15	2	1	7	3	3			1	4		1				1	1			1	
15	20	11	2	1	4		5			1	4	1	1	3	2	2		1	1		1	
Total:			22	20	##	56	##	30	35	48	280	11	120	65	28	45	120	125	30	33	210	1575

		heroin addicts						Grand Total
prices ($)		valium pills						
heroin	cocaine	0	1	2	3	4	7	
3	10	38	2	1				
6	10	32	7	2				
15	10	30	7	4				
30	10	30	8	1	1		1	
15	2	34	6	1				
15	4	34	4	3				
15	10	30	7	4				
15	20	31	5	1	3	1		
Total:			46	34	12	4	7	103

		cocaine addicts					Grand Total
prices ($)		valium pills					
heroin	cocaine	0	1	2	3	4	
3	10	37	1	2			
6	10	37	1	2			
15	10	37	1	2			
30	10	38		1		1	
15	2	36	2	1	1		
15	4	38		2			
15	10	37	1	2			
15	20	38		1		1	
Total:			6	26	3	8	43

		heroin addicts									Grand Total
prices ($)		packs of cigarettes									
heroin	cocaine	0	1	2	3	4	5	7	14	29	
3	10	6	8	15	5	6	1				
6	10	7	10	16	4	2	2				
15	10	9	2	23	2	1	4				
30	10	8	3	19	3	1	5	1		1	
15	2	6	13	14	5		3				
15	4	6	11	13	7		3		1		
15	10	9	2	23	2	1	4				
15	20	12	4	18	2		5				
Total:			53	282	90	44	135	7	14	29	654

		cocaine addicts														Grand Total
prices ($)		packs of cigarettes														
heroin	cocaine	0	1	2	3	4	5	6	7	8	9	10	14	15	35	
3	10	8	3	10	5	3	10									
6	10	8	4	9	5	2	10			1						
15	10	7	5	9	2	4	11						3			
30	10	7	5	8	3	3	13									
15	2	7	4	9	7	4	6	1	1		1					
15	4	9	8	8	5	3	4		1				2			
15	10	7	5	9	2	4	11						2			
15	20	8	4	7	4	4	8		1				1	1	1	
Total:			38	##	99	##	##	6	21	8	9	0	112	15	35	954

Table 3: Correlations between the experimental choices and real-life drug use

Years of regular use	Total units of that drug purchased in simulation
Heroin	0.843**
Cocaine	0.434**
Marijuana	0.505**
Alcohol	0.614**
Valium	0.402**

Breath or urine result positive	Total units of that drug purchased in simulation
Heroin	0.483**
Cocaine	0.111
Marijuana	0.331**
Alcohol	0.199*

* Indicates a p-value of 0.08.
** Indicates a p-value smaller than 0.01.

Table 4: Regression Results for Addictive Substances Demand using the Almost Ideal Demand System (Heroin Addicts Only)

Dependent var:	Heroin (w_h)				Cocaine (w_c)				Marijuana (w_m)			
# obs :	328		328		328		328		328		328	
Specification	**Unconstrained**		**Constrained**		**Unconstrained**		**Constrained**		**Unconstrained**		**Constrained**	
	GLS**				GLS**				GLS**			
Heroin price	-0.081	**	0.035	***	-0.047		-0.035	***	-0.034	*	-0.032	***
	(0.04)		(0.01)		(0.03)		(0.01)		(0.02)		(0.01)	
Cocaine price	-0.070	***	-0.035	***	0.030	**	0.035	***	0.003		0.032	***
	(0.02)		(0.01)		(0.01)		(0.01)		(0.01)		(0.01)	
Real expenditure (C/P)	-0.205	***	-0.129	**	0.006		0.014		-0.044		-0.041	
	(0.07)		(0.06)		(0.06)		(0.05)		(0.04)		(0.03)	
Age	-0.007		-0.007		0.003		0.003		0.003		0.003	
	(0.01)		(0.01)		(0.00)		(0.00)		(0.00)		(0.00)	
Male	-0.055		-0.072		-0.025		-0.027		0.032		0.032	
	(0.08)		(0.08)		(0.06)		(0.06)		(0.03)		(0.03)	
White	-0.083		-0.100		-0.046		-0.048		0.041		0.041	
	(0.08)		(0.08)		(0.06)		(0.06)		(0.05)		(0.05)	
Education years	0.031	*	0.034	*	-0.011		-0.010		-0.008		-0.008	
	(0.02)		(0.02)		(0.02)		(0.02)		(0.01)		(0.01)	
Employment problems	0.088	***	0.087	***	-0.042	**	-0.042	**	-0.028		-0.028	
	(0.03)		(0.03)		(0.02)		(0.02)		(0.02)		(0.02)	
Health problems	0.204		0.193		-0.167	**	-0.168	**	-0.074		-0.074	
	(0.15)		(0.16)		(0.08)		(0.08)		(0.08)		(0.08)	
Constant	1.111	***	0.614	**	0.302		0.249		0.150		0.075	
	(0.35)		(0.29)		(0.28)		(0.21)		(0.13)		(0.11)	
F-Stat	11.43		11.860		4.090		4.470		4.330		7.500	
*p value	0.000		0.000		0.000		0.000		0.000		0.000	
Homogeneity test $\chi 2(1)$	9.690				0.190				1.730			
Hom Test Prob > $\chi 2(1)$	0.002				0.665				0.188			
Symmetry test $\chi 2(1)$	12.790				12.790							
Sym Test Prob > $\chi 2(1)$	0.000				0.000							

Standard errors reported in parentheses.

*p value: Probability that P>F(k-l,n)

**Generalized Least Squares with heteroscedastic-consistent standard errors.

Table 4: Regression Results for Addictive Substances Demand using the Almost Ideal Demand System (Heroin Addicts Only)

Dependent var:	Alcohol (w_a)		Valium (w_v)	
# obs :	328	328	328	328
Specification	Unconstrained	Constr	Unconstrained	Constr
	GLS**		GLS**	
Heroin price	0.137 ***	0.032 ***	0.007	-0.002
	(0.04)	(0.01)	(0.01)	(0.00)
Cocaine price	0.027 ***	-0.032 ***	0.006 *	0.002
	(0.01)	(0.01)	(0.00)	(0.00)
Real expenditure (C/P)	0.224 ***	0.156 ***	0.005	-0.001
	(0.06)	(0.05)	(0.01)	(0.01)
Age	-0.001	-0.001	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Male	0.096 ***	0.111 ***	-0.017 **	-0.016
	(0.03)	(0.03)	(0.01)	(0.01)
White	0.056 **	0.072 ***	0.011	0.013
	(0.03)	(0.03)	(0.01)	(0.01)
Education years	-0.014	-0.017	0.003 ***	0.003 ***
	(0.01)	(0.01)	(0.00)	(0.00)
Employment problems	-0.028 ***	-0.027 **	-0.002	-0.002
	(0.01)	(0.01)	(0.00)	(0.00)
Health problems	0.012	0.022	0.013	0.014
	(0.05)	(0.07)	(0.02)	(0.02)
Constant	-0.457 ***	0.053	-0.070 **	-0.029
	(0.17)	(0.09)	(0.03)	(0.02)
R-sq	64.82	45.97	6.07	6.03
*p value	0.000	0.000	0.000	0.000
Homogeneity test $\chi 2(1)$	14.010		0.960	
Hom Test Prob > $\chi 2(1)$	0.000		0.328	

Standard errors reported in parentheses.

*p value: Probability that P>F(k-l,n)

**Generalized Least Squares with heteroscedastic-consistent standard errors.

Table 5: Regression Results for Addictive Substances Demand using the Almost Ideal Demand System (Cocaine Addicts Only)

Dependent var:	Heroin (w_h)		Cocaine (w_c)		Marijuana (w_m)	
# obs :	320	320	320	320	320	320
Specification	**Unconstrained**	**Constrained**	**Unconstrained**	**Constrained**	**Unconstrained**	**Constrained**
	GLS**		GLS**		GLS**	
Heroin price	-0.006	0.017 **	-0.024 ***	-0.017 **	0.002	0.047 ***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)
Cocaine price	-0.069 ***	-0.017 **	-0.117 ***	0.017 **	-0.059 ***	-0.047 ***
	(0.03)	(0.01)	(0.05)	(0.01)	(0.03)	(0.01)
Real expenditure (C/P)	-0.101 ***	-0.077 **	-0.141 *	-0.075	-0.121 ***	-0.116 ***
	(0.05)	(0.04)	(0.08)	(0.06)	(0.05)	(0.04)
Age	-0.006	-0.006	0.009	0.009	-0.002	-0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Male	0.045	0.042	-0.024	-0.032	0.023	0.023
	(0.05)	(0.05)	(0.08)	(0.08)	(0.05)	(0.05)
White	0.029	0.029	-0.103	-0.103	0.045	0.045
	(0.04)	(0.05)	(0.08)	(0.08)	(0.05)	(0.05)
Education years	0.024	0.024	-0.008	-0.008	-0.005	-0.005
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Employment problems	-0.051	-0.043	0.049	0.070	0.022	0.023
	(0.09)	(0.09)	(0.14)	(0.14)	(0.07)	(0.07)
Health problems	0.075 ***	0.065 **	0.028	0.002	-0.042	-0.043
	(0.03)	(0.03)	(0.08)	(0.08)	(0.03)	(0.03)
Constant	0.305	0.082	0.945 **	0.501	0.493 ***	0.342 *
	(0.34)	(0.32)	(0.44)	(0.38)	(0.22)	(0.17)
F-Stat	9.15	8.780	9.250	8.120	12.000	17.530
*p value	0.000	0.000	0.000	0.000	0.000	0.000
Homogeneity test $\chi 2(1)$	6.940		7.420		5.030	
Hom Test Prob > $\chi 2(1)$	0.008		0.006		0.025	
Symmetry test $\chi 2(1)$	8.960		8.960			
Sym Test Prob > $\chi 2(1)$	0.003		0.003			

Standard errors reported in parentheses.

*p value: Probability that P>F(k-l,n)

**Generalized Least Squares with heteroscedastic-consistent standard errors.

Table 5: Regression Results for Addictive Substances Demand using the Almost Ideal Demand System (Cocaine Addicts Only)

Dependent var:	Alcohol (w_a)		Valium (w_v)	
# obs :	320	320	320	320
Specification	Unconstrained	Constrained	Unconstrained	Constrained
	GLS**		GLS**	
Heroin price	0.025 ***	-0.025 *	0.001	0.000
	(0.01)	(0.02)	(0.00)	(0.00)
Cocaine price	0.174 ***	0.025 *	-0.001	0.000
	(0.04)	(0.02)	(0.00)	(0.00)
Real expenditure (C/P)	0.269 ***	0.197 ***	-0.002	-0.002
	(0.08)	(0.06)	(0.00)	(0.00)
Age	0.001	0.000	0.001 *	0.001 *
	(0.00)	(0.00)	(0.00)	(0.00)
Male	0.039	0.048	-0.004	-0.004
	(0.06)	(0.05)	(0.01)	(0.01)
White	-0.006	-0.007	0.015 **	0.015 **
	(0.05)	(0.05)	(0.01)	(0.01)
Education years	-0.004	-0.003	0.000	0.000
	(0.01)	(0.01)	(0.00)	(0.00)
Employment problems	-0.045	-0.067	0.011	0.011
	(0.09)	(0.10)	(0.01)	(0.01)
Health problems	-0.051	-0.023	-0.004	-0.004
	(0.07)	(0.07)	(0.01)	(0.01)
Constant	-0.697 ***	-0.098	-0.033	-0.034
	(0.21)	(0.19)	(0.03)	(0.03)
R-sq	27.07	17.53	11.14	12.50
†p value	0.000	0.000	0.000	0.000
Homogeneity test $\chi2(1)$	20.460		0.020	
Hom Test Prob > $\chi2(1)$	0.000		0.898	

Standard errors reported in parentheses.

*p value: Probability that P>F(k-l,n)

**Generalized Least Squares with heteroscedastic-consistent standard errors.

Table 6: Cross and Own Price Elasticities Using the Almost Ideal Demand System

Heroin Addicts Sample:

Demand	Price	Unconstrained SUR†	Constrained SUR†
Heroin			
	heroin	-0.917 ***	-0.818 ***
		0.003	0.003
	cocaine	0.001	0.017 *
		0.006	0.009
Cocaine			
	heroin	-0.182 ***	-0.159 ***
		0.009	0.010
	cocaine	-0.902 ***	-0.892 ***
		0.006	0.008
Marijuana			
	heroin	-0.055 ***	-0.048 ***
		0.009	0.012
	cocaine	0.091 ***	0.224 ***
		0.010	0.014
Alcohol			
	heroin	-0.289 ***	-0.792 ***
		0.013	0.026
	cocaine	-0.384 ***	-0.635 ***
		0.018	0.030
Valium			
	heroin	0.067 ***	-0.034 ***
		0.007	0.008
	cocaine	0.090 ***	0.042 *
		0.015	0.026
Cigarettes			
	heroin	0.242 **	0.012 *
		0.119	0.007
	cocaine	-0.025	-0.274 ***
		0.021	0.010

Cocaine Addicts Sample:

Demand	Price	Unconstrained SUR†	Constrained SUR†
Heroin			
	heroin	-0.913 ***	-0.882 ***
		0.008	0.010
	cocaine	-0.051 ***	0.057 ***
		0.001	0.002
Cocaine			
	heroin	0.189 ***	0.084 ***
		0.034	0.026
	cocaine	-1.051 ***	-0.896 ***
		0.003	0.004
Marijuana			
	heroin	0.100 ***	0.275 ***
		0.022	0.037
	cocaine	0.052 ***	0.090 ***
		0.005	0.008
Alcohol			
	heroin	-1.586 ***	-1.754 ***
		0.142	0.151
	cocaine	-0.057 ***	-0.941 ***
		0.014	0.024
Valium			
	heroin	0.015 ***	0.013 *
		0.006	0.007
	cocaine	0.006 **	0.011
		0.003	0.008
Cigarettes			
	heroin	-0.806	-0.916
		0.575	0.609
	cocaine	0.071	-0.347
		0.212	0.295

† Seemingly Unrelated Equations with standard errors corrected for heterocedasticity

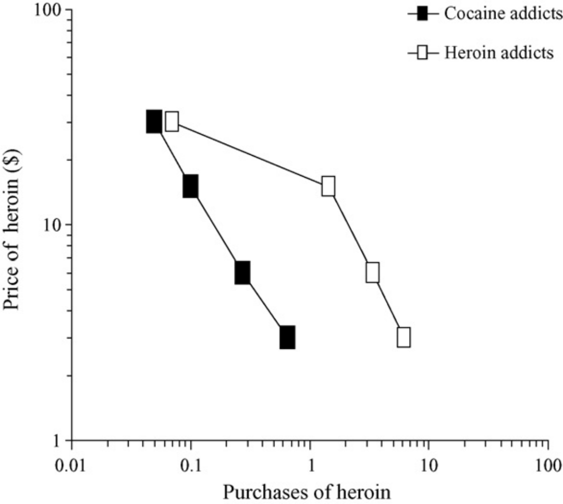
*, ** and *** indicate 90%, 95% and 99% level of significance, respectively.

The variances of the elasticities are calculated according to the formulae:

$Var(\varepsilon_{ii}) = Var(\beta_i) + Var(\gamma_{ii}) / w^2{}_i - 2\,\mathrm{cov}(\beta_i, \gamma_{ii}) / w_i$ for the own price elasticities

$Var(\varepsilon_{ij}) = 1 / w^2{}_i [w^2{}_j Var(\beta_i) + Var(\gamma_{ij}) - 2 w_j\ \mathrm{cov}(\beta_i, \gamma_{ij})]$ for the cross price elasticities

The budget share w_j is the individual's average budget share for product *j* and the coefficients' variances and covariances are the estimated ones.



Cocaine addicts
Heroin addicts
Price of heroin ($)
100
10
1
0.01
0.1
1
10
100
Purchases of heroin

Figure 1: Effects of heroin price changes on heroin purchases

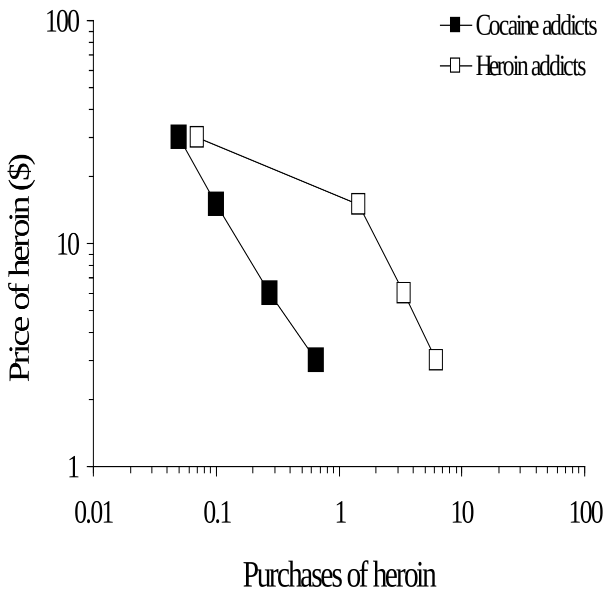


Figure 2: Effects of heroin price changes on other drugs' purchases in heroin (top) and cocaine (bottom) addicts

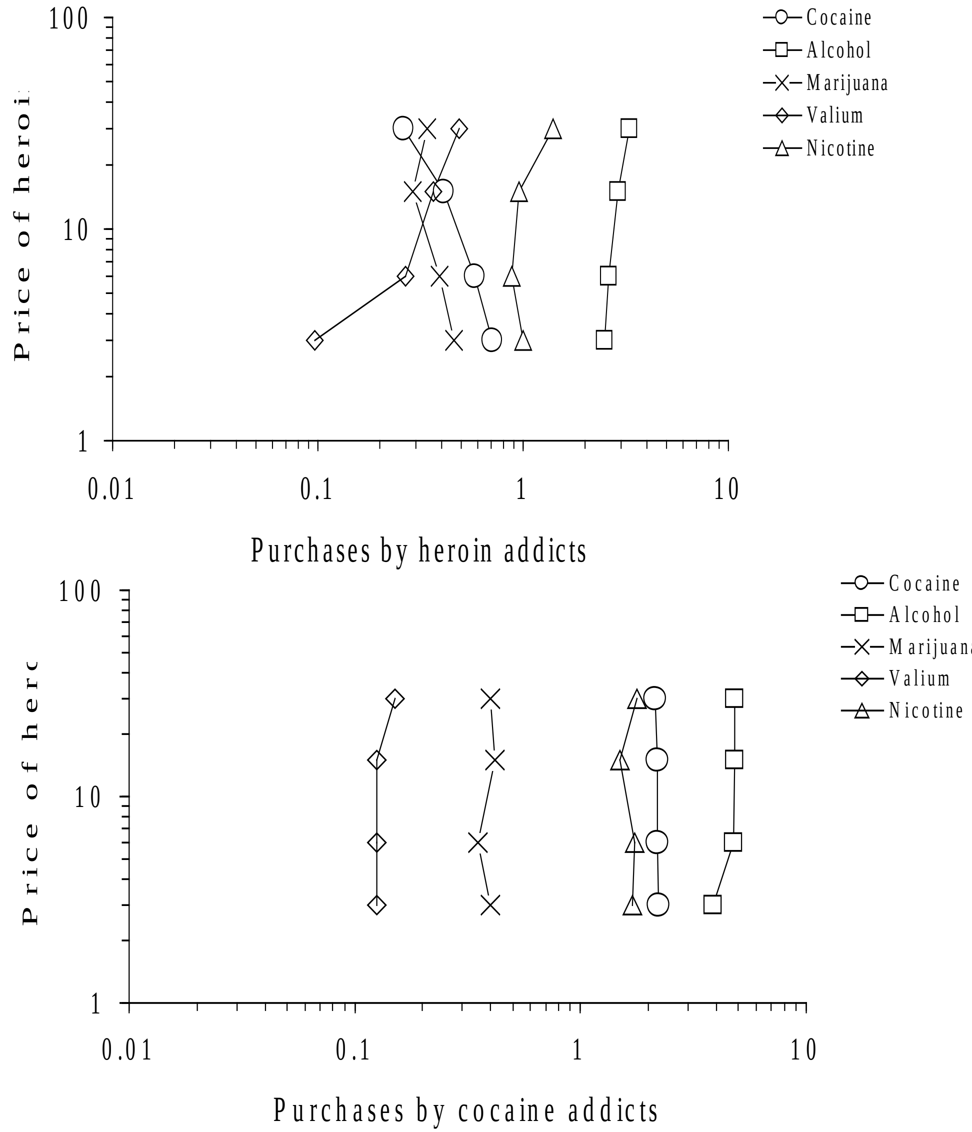


Figure 3: Effect of cocaine price changes on cocaine purchases

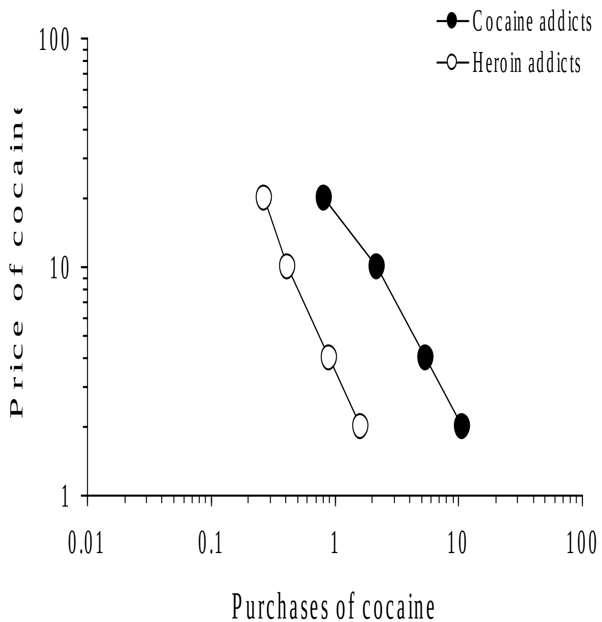


Figure 4: Effects of cocaine price changes on other drugs' purchases in heroin (top) and cocaine (bottom) addicts